

**REPORT ON MARS, NO. 39.****By WILLIAM H. PICKERING.**

## SEASONAL CHANGES OF DETAIL.

We have now reached that point in our knowledge of Mars, where we feel it safe to predict those apparitions during which rapid surface changes are likely to occur. Thus in 1924 we ventured to state that striking changes would probably take place upon the planet in 1926, and in our Report No. 36 illustrated what some of these changes would be like. Although other changes will without doubt be recorded at the next apparition, few as marked as these, and as wide spread, are likely to occur again before 1937. It must be understood that these predictions were based solely on what we had seen occur at previous apparitions, at a certain time in the Martian year, namely the winter season of its northern hemisphere. I had never seen the planet near at hand at this season, and my views of the details of its surface were therefore somewhat indistinct. Moreover the question arose in my mind, was it not possible that the changes observed were a mere illusion, caused by the remoteness of the planet? I felt sufficiently sure of my drawings, however, to venture the prediction, but was naturally very anxious to see how it would turn out, and how the planet would look near at hand when these changes were actually taking place upon its surface. It must be understood, as was pointed out in Report No. 36, that while we can now predict the approximate time at which these changes will take place, and their approximate character, it is quite impossible, since they are due mainly to the formation of or the precipitation from Martian clouds, to foretell their exact shapes, or the exact dates at which they will occur. During this last apparition a change moreover took place in the Thaumasia region, whose character we only partially expected, since it had never previously been recorded, and which we shall deal with presently. First, however, we will look at some of the more fully expected changes.

On Plate VII the first two columns of figures are reprinted from Report No. 36. The first column gives the usual appearance of these regions, and the second shows the changes that they incurred in the years 1913, 1924, and 1925. The figures in the third column were all drawn at this last apparition, and show similar changes occurring at about the same season of the year. Under each figure is given the date on which the drawing was made, followed by the longitude  $\omega$  of its central meridian. Below that is given the solar longitude  $\odot$ , and the corresponding Martian date. Supplementary data are given in Table I, where the first two columns give the number of the figure, and the number given to it in Report No. 36. Next follow the latitude of the center of the disk, its diameter, and the quality of the seeing. The last

two columns give the difference in the solar longitude of the two figures that resemble one another, and the corresponding difference between the Martian date in 1926 and that in the earlier years expressed in Martian days. The plus sign indicates that the expected change in 1926 came later in the Martian year than the change observed in the earlier years.

Turning now to the drawings themselves, Figure 1 shows the Syrtis, or Syrtis major as Schiaparelli called it, to the right or west of the central meridian, and the Syrtis minor, greatly enlarged as it appeared at one time in 1924, on the right. The bright region between them, just north or below the center of the disk is known as Libya, and was early recognized by Perrotin as a region which sometimes turned dark (Reports Nos. 27, 12, 25, Figures 21, 22, and 24, and 29, Figure 23). Figure 2 is drawn with the central meridian in longitude  $294^\circ$ , or differing by  $24^\circ$  from that of Figure 1. In consequence the Syrtis is now brought to a position just below the center of the disk. As a result of the recent melting of the southern snow cap, a yellowish cloud is seen in the place of the latter, and other clouds cover a large part of the southern hemisphere. Still farther north another cloud partly covers a portion of the Syrtis itself, leaving the tip, however, faintly visible. Libya has obviously darkened, while the Syrtis minor has disappeared.

It was reasonable to expect, based on our previous knowledge, that this change would occur again in 1926. Indeed it occurred twice, on August 19, and again on December 4, with Libya bright for most of the time between the two. The drawing of the earlier date is given in Figure 3, which has approximately the same central meridian as Figure 1, and not a very different latitude, as we see by Table I. It will be noticed by the last column of the Table that in 1926 the change occurred 82 Martian days earlier than it did in 1924. On the other hand the second darkening in December occurred 23 Martian days later than in 1924. We thus see how hopeless it is to attempt to predict accurate dates for the appearances of the Martian changes.

TABLE I.  
CHANGES EXPECTED IN 1924 TO OCCUR IN 1926.

Fig.	36	Lat.	Diam.	Seeing	$\Delta\odot$	Days
1	3	$-20^\circ$	16".3	10		
2	20	$-25$	8.7	7		
3	..	$-15$	13.2	6	$-50.4$	$-82$
4	13	$-18$	18.7	10		
5	16	$+3$	7.8	8		
6	..	$-13$	15.9	10	$-39.2$	$-65$
7	14	$-25$	9.5	6, 7		
8	..	$-20$	17.4	5	$+14.1$	$+25$
9	9	$-22$	13.2	7		
10	11	$-24$	7.1	8, 7		
11	..	$-20$	17.4	5	$-6.5$	$-10$
12	21	$-23$	12.9	8		
13	22	$-25$	8.9	8		
14	..	$-20$	16.6	8	$+12.3$	$+22$

PLATE VII

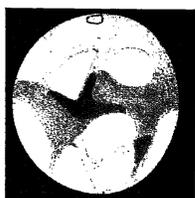


Fig. 1  
'24 Oct. 19, 270°  
278°.4 Dec. 25

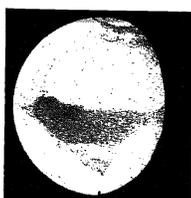


Fig. 2  
'24 Dec. 23, 294°  
317°.0 Jan. 33

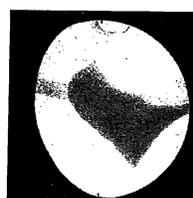


Fig. 3  
'26 Aug. 19, 261°  
266°.6 Dec. 6

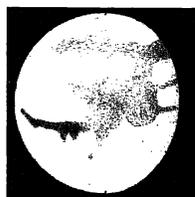


Fig. 4  
'24 Oct. 5, 29°  
269°.7 Dec. 11

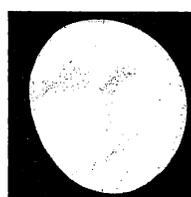


Fig. 5  
'13 Sept. 17, 36°  
320°.9 Jan. 40

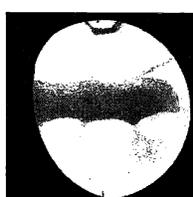


Fig. 6  
'26 Sept. 12, 33°  
281°.6 Dec. 30

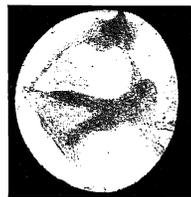


Fig. 7  
'24 Dec. 13, 33°  
311°.3 Jan. 23

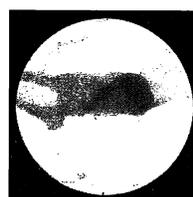


Fig. 8  
'26 Nov. 26, 29°  
325°.4 Jan. 48



Fig. 9  
'24 Nov. 8, 60°  
290°.7 Dec. 44



Fig. 10  
'25 Jan. 19, 60°  
331°.9 Feb. 3

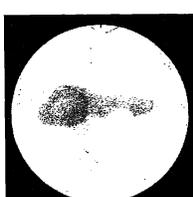


Fig. 11  
'26 Nov. 26, 62°  
325°.4 Jan. 48



Fig. 12  
'24 Nov. 10, 359°  
291°.9 Dec. 46

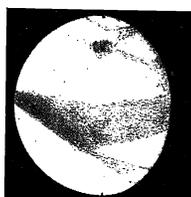


Fig. 13  
'24 Dec. 21, 1°  
315°.9 Jan. 31



Fig. 14  
'26 Dec. 1, 1°  
328°.2 Jan. 53

DRAWINGS OF MARS.

POPULAR ASTRONOMY, No. 344.

PLATE VIII

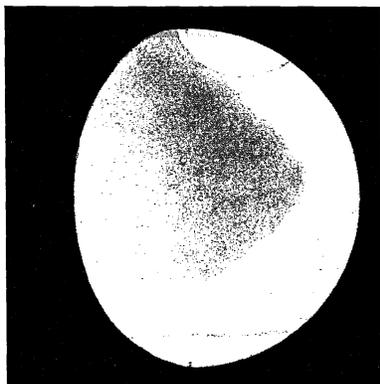


Fig. 15  
'26 June 27, 121° 9'3  
232°.7 Nov. 9, -22°.2

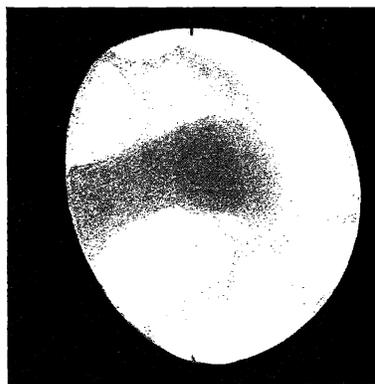


Fig. 16  
'26 Aug. 7, 74° 12'1  
259°.1 Nov. 50, -17°.1

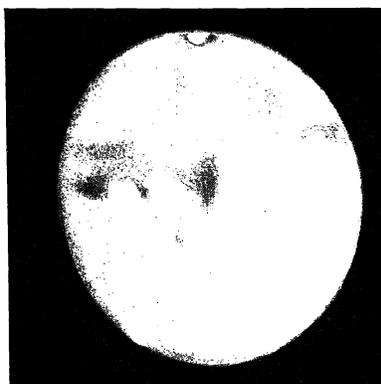


Fig. 17 Phillips  
'26 Sept. 5, 82° 15'1  
277°.3 Dec. 23, -13°.2

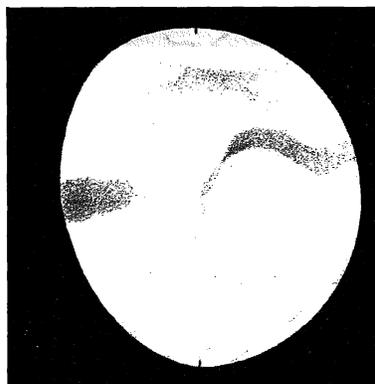


Fig. 18  
'26 Sept. 5, 119° 15'1  
277°.3 Dec. 23, -13°.2

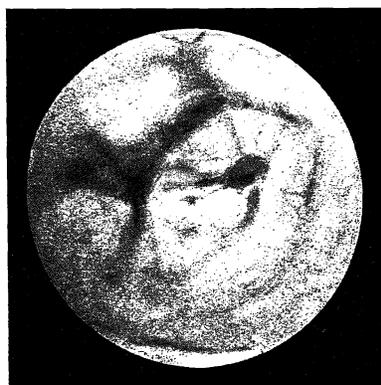


Fig. 19 Wilson  
'26 Oct. 20, 60° 20'2  
304°.5 Jan. 12, -14°.2

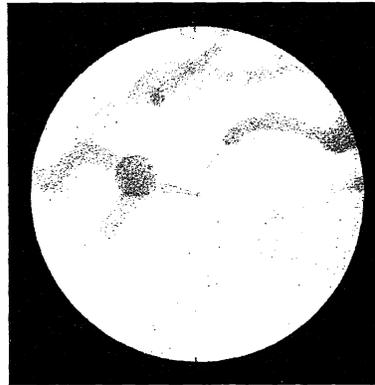


Fig. 20  
'26 Nov. 17, 119° 18'8  
320°.4 Jan. 39, -18°.6

DRAWINGS OF MARS.

The next change was due to an unusually strong development of certain canals, caused obviously by the transfer of the moisture across the planet's surface. This was combined with a very thick haze in the dense Martian atmosphere. Our first drawing, Figure 4, was made before this occurred, and the planetary details are clearly seen. Sabaeus with the Furca is shown on the left of the disk, Margaritifer with the little Oxia below it on the central meridian, and the broad gulf of Aurorae on the right. The drawing Figure 5, based on which the change was predicted, was not made in 1924, however, but in 1913. Owing chiefly to the difference in phase between the two drawings, as shown by the short lines marking their poles, Aurorae is here brought nearer to the center of the disk, and Ganges, Jamuna, Nilokeras, and Chryssorroas form broad bands faintly seen through the mist. In Figure 6, drawn at the past apparition, Aurorae is located well to the right of the central meridian as in Figure 4, and Ganges descends from it to a large darkened area which is really Lunae, but is here extended unusually far towards the right, enveloping Chryssorroas. An unusual canal, Lowell's Phryxus, stretches out to the left. To the right of Aurorae is a darkened area extending over Thaumasia, which we shall later more fully describe.

The next change to which we shall refer occurred two months later in this same area, which, as mentioned in previous Reports, is noted for its changes. We need not therefore repeat Figure 4, but will refer Figures 7 and 8 to it. In both of these figures Aurorae is seen well to the right of the central meridian, with Ganges descending from it as a broad band towards the northwest. About as far to the right of the central meridian, and in both cases rather farther to the north, we recognize the Furca, although its two bays cannot now be separated. It is comparatively faint, and the difference of these drawings from Figure 4 is rather strongly marked. Both the later drawings show a pair of southern canals extending up towards the polar cap, as well as some broad northern canals not seen in Figure 4, which is freer of haze, and is more clearly defined. Dealing still with this same general region, but in a slightly higher longitude, we have in Figure 9 Aurorae just below the center of the disk, and the dark Solis to the right and above it, the two being joined by the narrow Nectar. In Figures 10 and 11, in practically the same latitude and longitude as Figure 9, the whole disk is dimmed by Martian haze, but Nectar and Solis are much larger, while Ganges in the three drawings shows three different states of development. The darkening to the right of Aurorae, mentioned in connection with Figure 6, shows again, but is somewhat narrower than in the earlier drawing.

In Figure 12 we find Sabaeus well marked and just below the center of the disk. In Figure 13 with practically the same central meridian it has nearly or quite faded out, while Deucalionis, the bright region to the south of it, has darkened as far south as Pandorae. Figure 14 shows an intermediate development in these respects. Much farther south in

the last two figures we see a conspicuous lake at the intersection of four canals, which replaces a much larger dark area visible in Figure 12. The northern left hand of these canals is evidently Hellespontus, shown as a very dark rounded canal in Figure 12, and as two or three times as wide in previous apparitions. The right hand northern canal in Figure 13 must be its continuation, but very much narrowed as compared with Figure 12, while the two canals of Figures 13 and 14 flowing towards the southeast are probably identical. In a drawing made on July 9, 1926,  $\odot 241^{\circ}.0$ , the lake and the two southern canals of Figure 13 are clearly shown, as well as the canal leading northerly from the lake, shown in Figure 14, thus confirming both drawings where they differ from one another. Another drawing made August 12,  $\odot 262^{\circ}.4$ , also confirms the northern canal in Figure 14.

Gehon is one of the best known of all the canals, and in all the drawings of Reports Nos. 34 and 35 leaves the Furca in a northerly direction. The corresponding canals in Figures 13 and 14 therefore are either not identical with Gehon, or else show a notable shift towards the west in their orientation. This orientation is corroborated by Figure 23 of Report No. 36, drawn at another presentation. In somewhat earlier drawings in both 1924 and 1926 Gehon is invisible, while in still earlier ones it leaves the Furca, as we have above noted, in a northerly direction. This latter agrees with the Antoniadi map of Report No. 15, while Lowell agrees with neither, but draws Gehon with an intermediate direction. He indicates, however, a faint nameless double canal travelling due north. In the writer's map of Report No. 36, based on the five apparitions of 1914 to 1922, one canal only is shown travelling due north. It would appear therefore that two canals, one nameless, are involved. Each at different times, when it only was visible, has been called Gehon. It may be noted incidentally that Schiaparelli inclines Gehon slightly to the *east* of north.

On comparing the diameters of the similar drawings shown in the last two columns of the plate, by means of the fourth column of Table I, we see that in the last year the apparent size of the planet was larger by from 1.5 to nearly 2.5 times. The resemblances nevertheless are fairly close, in spite of the smaller diameters when the earlier drawings were made. Neither was there very much more detail shown in the later drawings, although this last was possibly in part due to the difference in the instruments employed. We therefore conclude that these marked changes in the planet's appearance during its cloudy seasons, in the earlier drawings were due, not to errors caused by its small apparent diameter, which in none of these cases exceeded  $9''.5$ , but were genuine changes occurring upon its surface. And we further conclude, from a study of the Table, that we should not neglect to study the planet under favorable atmospheric conditions, even when its diameter is reduced to as little as  $7''$ . Besides the five cases above described, where curious and marked changes of detail observed in 1913, 1924, and 1925, and therefore predicted for 1926, have been verified with more

or less accuracy, there are about a dozen more, where less marked changes have occurred, but where the resemblance between the drawings for the different years is about equally close. Perhaps the most striking of all those that were predicted, however, remains yet to be described, but since the appearance at one time was distinctly different from that noted in 1924, it has been thought best to place it in a class by itself.

#### CHANGES IN THAUMASIA.

This curious phenomenon was first recognized in Arequipa in 1892, but seen to much greater advantage thirty years later, and again at the last apparition. It has been recorded by us about a dozen times on many different drawings, but does not seem to have been noted elsewhere, or at all events described. It appears to be associated with the melting of both of the polar caps, and consists in a simple darkening of the whole region of Thaumasia, and sometimes of the region surrounding it, so that neither Solis nor the great canal Agathodaemon are visible, nor can we distinguish Thaumasia from Aurorae and the region to the south of it.

My first observation of Mars in 1926, with my new 12.5-inch Calver reflector, was made on June 27,  $\odot$   $232^{\circ}.7$ , some four terrestrial months before any notable changes were expected to take place on the planet. Judge then of my surprise to find nearly half of the disk darkened, Figure 15, and no other recognizable detail, save the two polar caps, visible upon it. The diameter of the planet was  $9''.3$ , the seeing 6 and 7, and the latitude of the center  $-22^{\circ}$ , as stated beneath the figure. The region that I expected to see was that of Thaumasia. Figure 20 is drawn with very nearly the same central latitude and longitude, and although its detail has an unfamiliar aspect, yet it will serve to show the region of the planet that was under inspection. The circular dark spot to the left of the center is Solis. More than halfway from it to the left limb lies Aurorae, while the dark area slightly above it and to the right of the central meridian is Sirenum, with Titanum close to the limb. The bright area of Thaumasia lies between Aurorae and Sirenum. This region we see by Figure 15 is completely darkened. Titanum is covered by limb cloud and is invisible. Aurorae in this figure would be beyond the terminator. This drawing is confirmed by a similar one made by Mr. Wilson the next night, central longitude  $\omega$   $64^{\circ}$ . The same region is shown in a more familiar aspect but with a different central longitude in Figure 19.

Our next drawing which is not shown here, was made on July 3,  $\omega$   $57^{\circ}$ . The dark area had notably diminished in size, being of about the same size as the darker portion of Figure 16, but of an entirely different shape. This was mainly due to a different distribution of the terminator and limb clouds. There is in the earlier drawing, however, a broad dark band reaching from the western side of the southern polar cap towards the center of the disk, confirmed by another drawing made

on July 5, and also by one of Mr. Wilson made on June 29,  $\omega$   $58^\circ$ , but which is not found in Figure 16. This broad band evidently dried up, since it crossed at right angles the place of the similar, but much narrower band shown in the latter Figure. In the earlier drawing the eastern portion of Thaumasia is still completely darkened, while the western is covered by a dense bright cloud.

A curious fact must now be mentioned. The solar longitude  $\odot$  when this drawing was made was  $237^\circ.1$ . In 1924 Thaumasia was perfectly clear at this Martian season, as shown by two drawings by Phillips and Du Martheray made on the nights of terrestrial August 12 and 15,  $\odot$   $235^\circ.6$  and  $237^\circ.4$ , Report No. **35**. Indeed the very best drawings of the planet in 1924, when it was nearest us, were made in the solar longitudes between  $229^\circ$  and  $262^\circ$ , whereas between these Martian dates in both 1922 and 1926 the planet was densely clouded. Just think what we should have missed if we had had the 1926 Martian weather in 1924! Similarly the Martian season that gave us our very best results in 1926,  $\odot$   $300^\circ$  to  $326^\circ$ , Martian dates January 4 to 49, was particularly cloudy and unfavorable in 1913, 1924, and 1925. The drawings made during this period in 1926, when the planet was nearest us, and when these regions were all particularly clear, will appear in a later Report, in connection with those of the other observers. Two of these drawings, however, are shown here in Figures 19 and 20. The former may be compared with Figures 5, 7, and 10, of nearly the same region, made in 1913, 1924, and 1925, at nearly the same season of the Martian year. Again in 1922 which was also a close apparition, the planet's atmosphere was filled with cloud until two weeks after the date of opposition, which then came quite early in the planet's year, but it then cleared off, and gave us splendid views for the twelve weeks following, after which heavy precipitation again occurred, blotting out many of the most interesting features.

There appear to be two fairly defined cloudy seasons on Mars, one in the late summer and one in the late winter, about the time when the snow caps are largest. Another cloudy season lasting eight or ten weeks sometimes occurs between them in the autumn. These facts are illustrated in Figure 21. Sometimes the beginnings and endings of these cloudy seasons are well marked, especially if they occur near the time of opposition, when the planet is well seen. At other times they seem to fade away, or to alternate with short periods of clear weather. In the Figure the abscissas at the top are solar longitudes. At the bottom are given the corresponding Martian months. Four terrestrial years are shown at the left hand. The heavy lines indicate the cloudy spells, and the dots the periods when they are uncertain. The three short vertical lines indicate the dates of opposition. Thus in 1922 we see that the planet's atmosphere cleared immediately after opposition. In 1924 there was a very long clear spell possibly beginning in Martian September. The best drawings were secured at about the time of opposition in November. We see, however, that both in 1922 and 1926 the

planet was clouded at this time. In 1926, as predicted in Report No. 36, the clear spell terminated at about the time of opposition, and the winter cloudy season began in late Martian January—our December. It may be mentioned in this connection that in 1892 opposition occurred the last of Martian October, and that all of October and November were clear, a long cloudy spell occurring in September. Whether the supposed Martians are able to control their weather, or whether as with us it is merely a question of chance, we were certainly very fortunate at all four of these close apparitions of the planet, to have their clouds clear off at the times when it was nearest to us, and we could observe it to the best advantage.

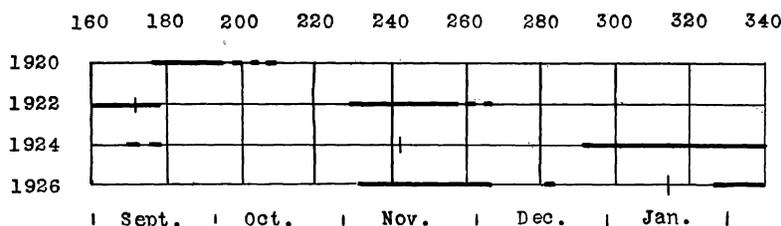


FIG. 21.  
CLOUDY SEASONS ON MARS.

Our next two drawings of this region were made on August 1 and 5,  $\omega$  124° and 49°. In the first, heavy clouds prevailed over Thaumasia, and probably to the north of it. In the second, clouds covered the surface all around the limb and terminator, leaving visible only a little central dark area, and the southern polar cap. Two days later a general clearing occurred, and in Figure 16 we note that the longitude of the central meridian,  $\omega$  74°, differs but little from that of Figure 17. From this we see that Thaumasia is still dark, and the *mare* to the west of it still covered by cloud. A number of observers in response to my request have kindly sent me drawings of this region, but as far as I can determine from my own drawings and from those of Mr. Wilson, the earliest other observer, Thaumasia was probably dark all the time from June 27 through August 7, and the lightening detected on August 1, which showed no detail, was I believe, as above stated, due merely to Martian cloud. We must notice that Figure 16 indicates that the darkening extends to nearly 5° north of the equator in longitude 106°, or to about 20° north of Phoenicis.

Our next drawing, Figure 17, is by Mr. Phillips, who seems to have been the first observer to clearly see surface detail in Thaumasia itself at this apparition. The first drawing that he sent me was dated August 27, but the only noticeable difference between it and the one here shown is that the short prolongation of Solis towards the south, indicated in the Figure on the central meridian, crossed the bright space between Solis and the polar cap. This canal is shown by Wilson and others, though I myself did not see it. This drawing must certainly look singu-

lar to those who have been accustomed to this region only during the last dozen years. The very curious meridional pointed shape of Solis strikes us at once. This I believe has never previously been noted, although often in the past it has been recorded as round. It was last observed as fairly round in 1901, but not so completely so as it appeared somewhat later in the past apparition. A very striking disappearance is that of Agathodaemon between the lakes of Maeisia and Phoenicis, also of the dark boundary of Thaumasia immediately to the south of Sirenum.

Our next drawing, Figure 18, was made on the same day as that of Mr. Phillips, and only two and a half hours later. It has the same central longitude as Figure 20. Its most striking feature is the great width of Nectar, which is on the terminator, and appears here as a broad band. This is confirmed by a similar drawing made on the previous night. Objects near the limb and terminator are never as well seen as when near the central meridian, but it is certain that they sometimes undergo a distinct change of shape under a low sun as distinguished from that which they present when the sun is high. In both Mr. Phillips' drawing and mine, Araxes, which descends from Sirenum to Phoenicis, is convex to the southeast, instead of to the northwest as is customary, implying a temporary shift of location. The break in the southern boundary of Thaumasia just south of Sirenum, which is shown in his drawing, has been closed in mine, and a number of northern canals have appeared which would have been too near the limb for him. When Solis was near the central meridian two days later, I drew it nearly circular, but slightly longer in a meridional direction. Mr. Phillips also sent a drawing dated October 6,  $\omega 74^\circ$ , which shows Solis of much the same shape as in Figure 17, but more blunted at the north. The curious feature, however, is that it is now divided into three parts, as if it were crossed by two narrow, parallel, east and west clouds, one lying north of the other. The northernmost of these clouds he also shows on October 2. He represents the southern canal from Solis as again complete, while the one towards the southwest is now missing. Changes in the southern boundary of Thaumasia have also occurred. These effects are all of them probably attributable to shifting clouds. A drawing by Schofield dated October 31,  $\omega 60^\circ$ , shows Solis separated from Nectar by a small narrow cloud lying in a north and south direction.

Figure 19 of October 20 by Mr. Wilson is interesting for several reasons. In the first place, except for the missing section of Agathodaemon, the general appearance of Solis and Thaumasia is much what we have been accustomed to during the past twelve years. In our previous drawings we may have noticed that Nectar apparently sometimes occupies two different positions, its eastern end being at times further north than its western one, in which case it is nearly in contact with Agathodaemon, as in Figure 9, and at other times it seems to lie to the south of it, as in Figures 17 and 20. Whether it really swings back and forth, or whether there are two separate canals whose appearance

usually alternates is not certain, but Wilson's drawing, Figure 19, where both are shown at the same time clearly implies that the latter is the case. He also shows a little lake and a very narrow canal just to the north of Nectar. He shows this lake also on October 15. We secured no drawing of this region on or between these two dates, and only an inferior one on October 26. Schofield, however, has sent a drawing from Japan, dated October 25, showing Nectar as a triple canal, but he does not show the little lake. Otherwise it confirms Wilson's drawing. It also confirms the "irrigation" canal of 1924. Although our drawing of October 26 was a poor one, with bad seeing, yet together with Schofield's it does seem to confirm Wilson's representation of Thaumasia and Solis as having returned to their customary form. This is the more important because our last drawing, Figure 20, made four weeks later, November 17, shows that they had then again resumed their appearance as first recorded by Phillips. It shows the southwestern boundary complete, but a part of Agathodaemon still is missing. Solis appears very nearly round, and a long well marked canal, Tithonius-Fortunae, extends from it towards the north pole. This canal is clearly confirmed by Wilson on October 14, and was very pronounced in a drawing made by myself on October 12. It was evidently not a permanent feature however. Most of the northern detail shown in the Figure was confirmed on this latter date. In December Thaumasia darkened again, at first appreciably less than the surrounding *maria*, but later it was indistinguishable from them. On December 27 and 28 the central portion of the disk alone showed detail, the rest being completely hidden by cloud. In our drawings in early January, the whole Martian sky was filled with such dense haze that the *maria*, even where darkest, were only slightly darker than the desert regions. Later the sky cleared, but when the Thaumasia region again became visible to us, January 28 to 31, nothing could be seen but dense Martian cloud, Seeing 9. The diameter at this time was 9".

An interesting feature of this past year's observations was the various shapes attributed to Solis by the different observers. Its mean diameter in the case of Figure 20 was 470 miles. It was therefore by no means a small object. Wilson gave it an indefinite but changeable shape in September, gradually assuming the usual elliptical form of former apparitions in October. In November he saw it more or less rounded, but on Nov. 22 the pointed shape given by Phillips was recorded. Ellison in Ceylon and Schofield represent it as rounded in October. Ellison surrounds it with projecting bays where the canals enter it. To myself both before and after October, its shape when near the central meridian was elliptical, with its major axis lying in a meridional direction, the ratio of the two axes being about 1.16. A striking exception is shown when near the terminator in Figure 18. In one of my drawings on October 12 it was rhomboidal, with a strongly inclined major axis, while only two hours earlier it had shown the usual elliptical form. Twice in November it was drawn circular, with a